Impact of Landfill Closure Designs on Long-Term Natural Attenuation of Chlorinated Hydrocarbons

Doug Downey
PARSONS
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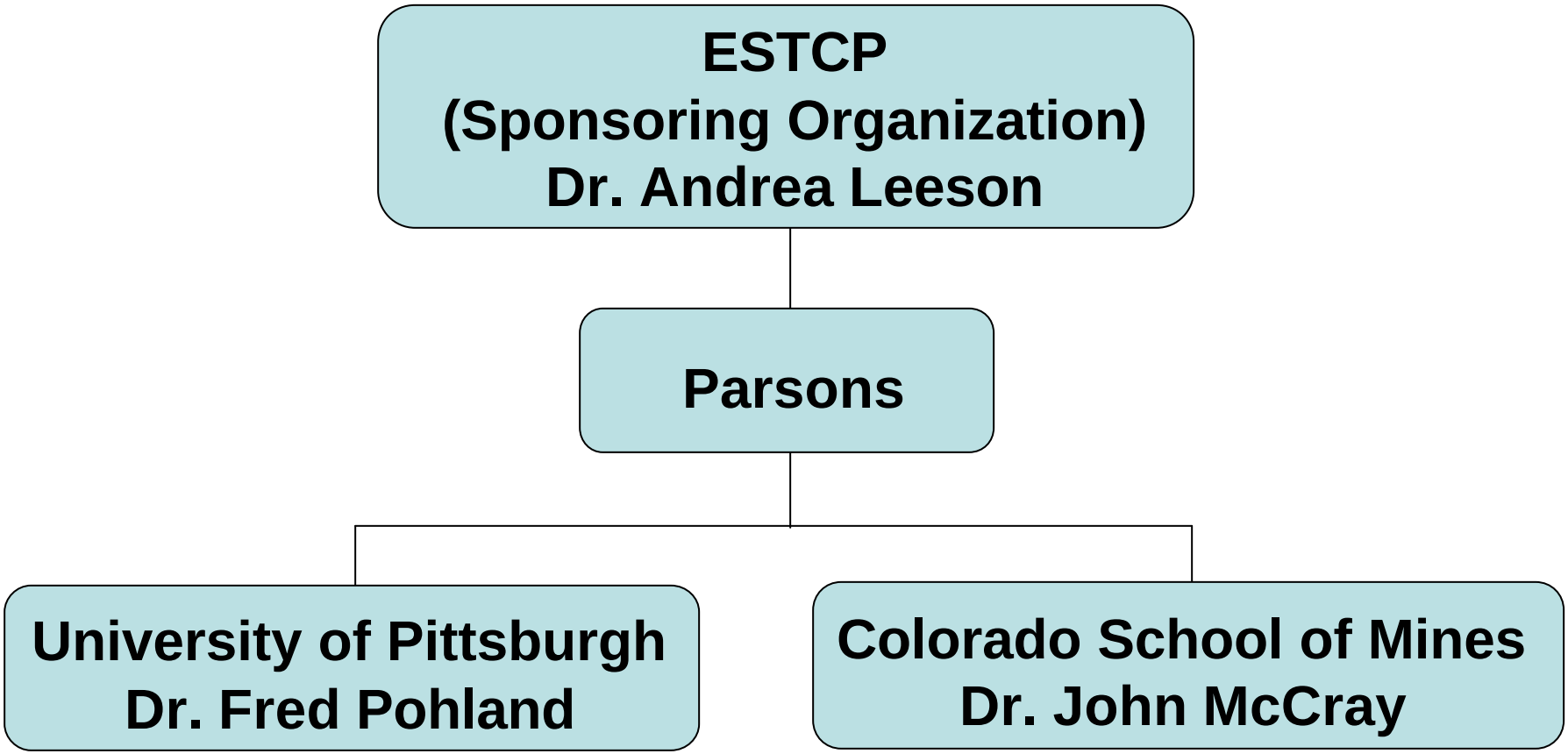
Objective

- **Develop alternative landfill closure designs and management strategies that can enhance long-term natural attenuation of chlorinated solvents in DoD landfills and leachate-contaminated groundwater**

Task Descriptions

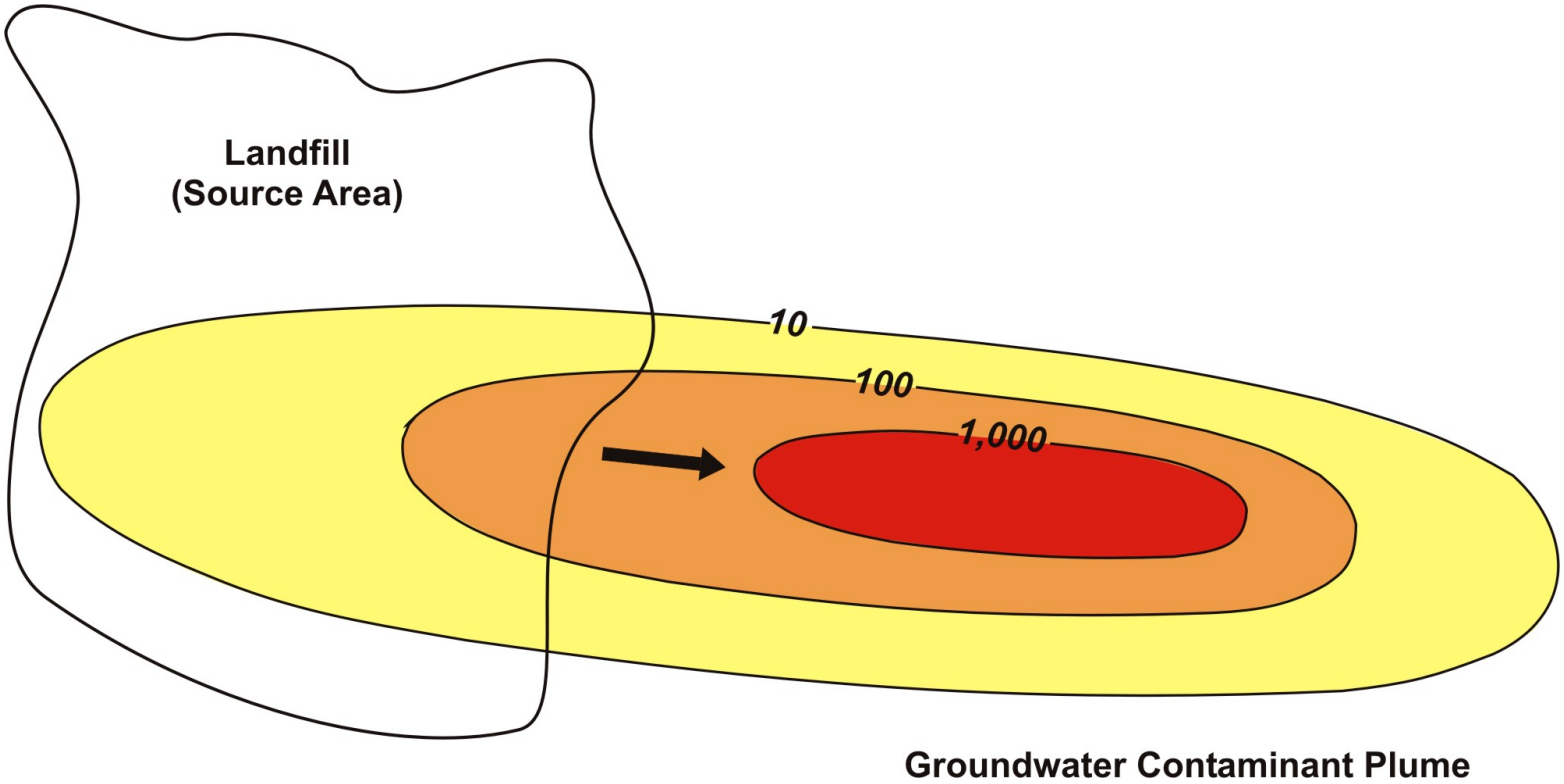
- Literature Review
- Landfill Data Review
- Conceptual Landfill-Design Model
- Technical Report

Project Organization

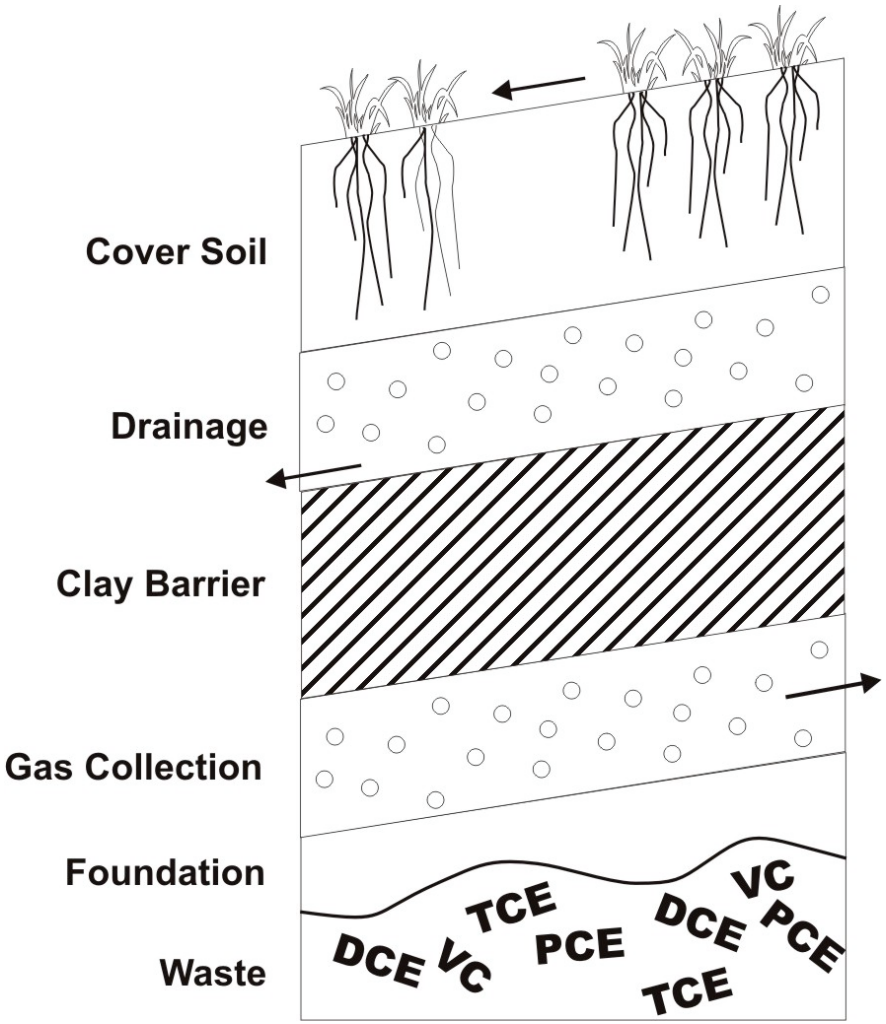


Background

- **Hundreds of landfills on DoD installations have generated CAH plumes in groundwater**



Problem

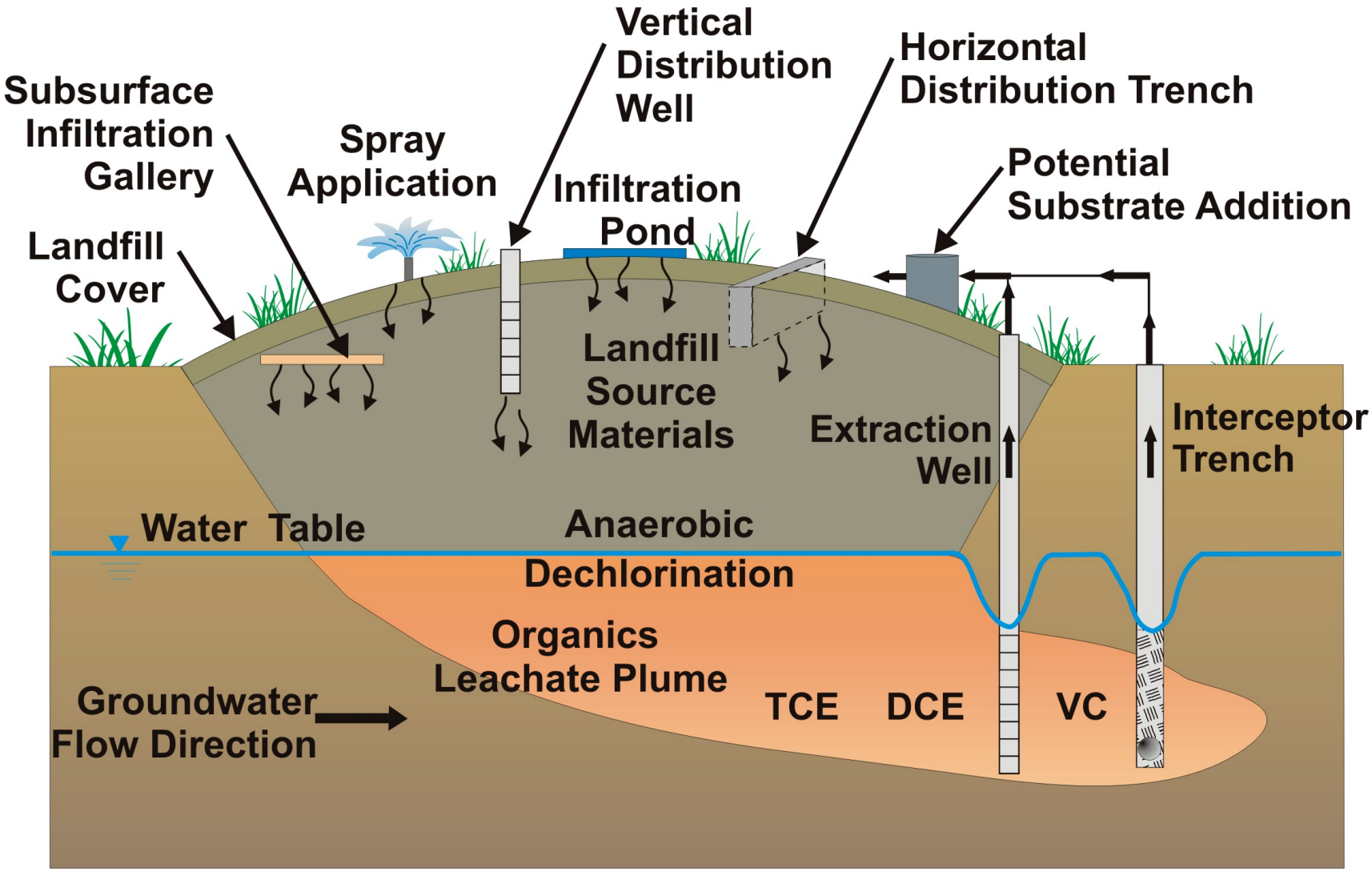


- Conventional landfill closure strategy is expensive and not always warranted
- Impermeable covers may impede natural attenuation processes
- Landfills have become “dry tombs”

A Solution

- The “enhanced leaching” theory of landfill treatment may provide more efficient and permanent waste-management solutions
- “Bioreactor” landfills utilize leachate recirculation to accelerate source leaching and promote waste biodegradation and stabilization within a “closed-loop” system
  - Concept conceived during the 1970s
  - Primarily applied to newer landfills

Schematic Cross-Section of Landfill Bioreactor Components

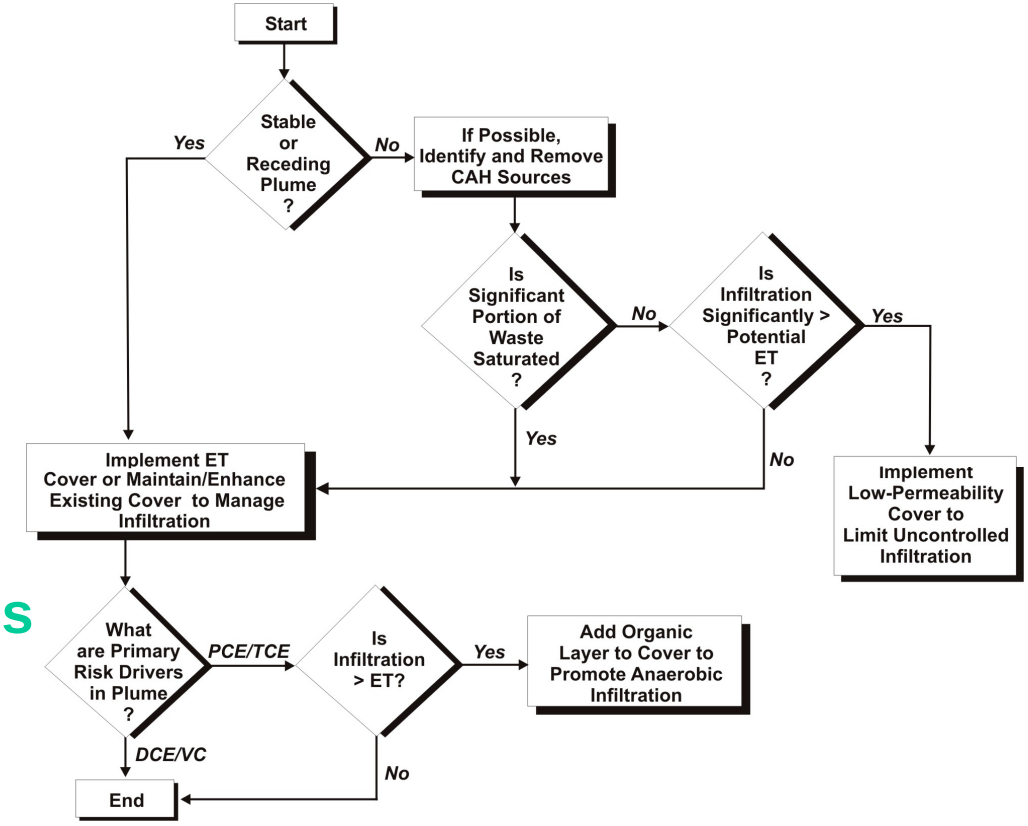


Regulatory Considerations

- 1993 – Source containment presumptive remedy for MSW landfills under CERCLA
- 1996 – Presumptive remedy should be applied to appropriate military landfills
- Recent paradigm shifts within USEPA
  - Risk-based/performance-based corrective action approaches
  - RCRA reforms of 2001 promote use of innovative approaches
  - More-favorable framework for innovative management strategies
  - USEPA is sponsoring Bioreactor landfill research

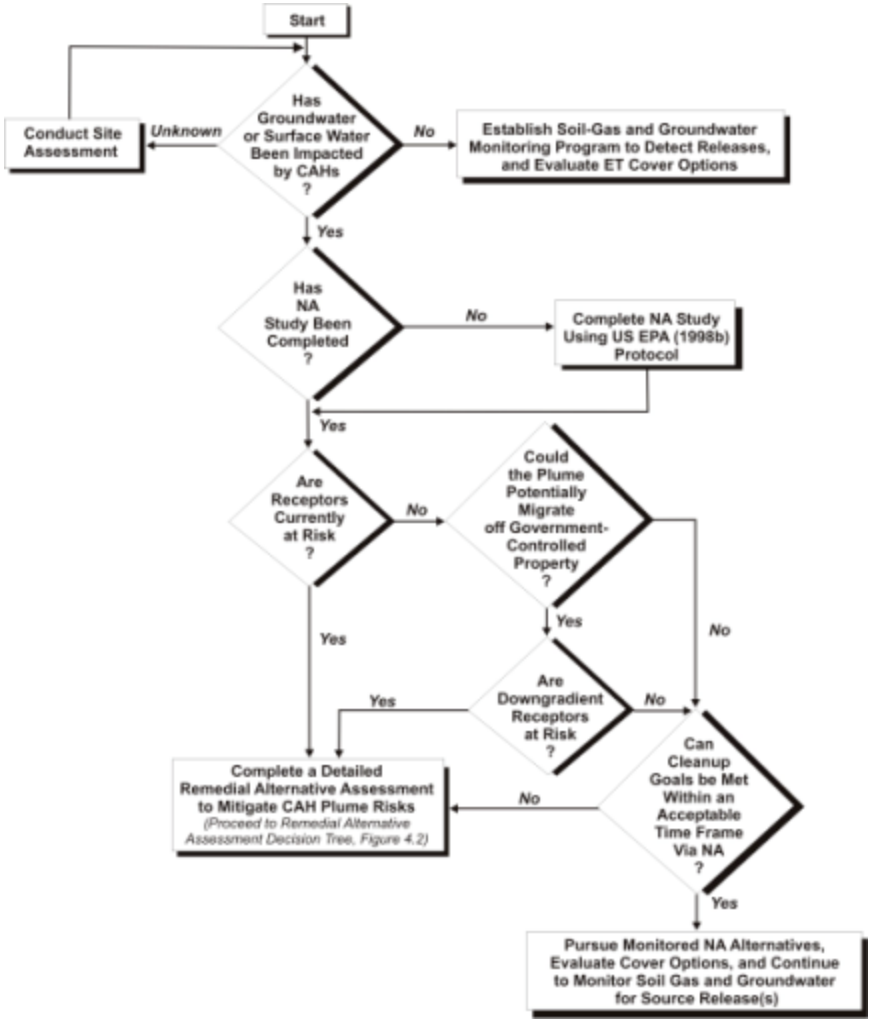
Decision Trees

- **Developed to assist DoD RPMs select an appropriate remedial strategy**
  - **Landfill Screening**
  - **Remedial Alternative Assessment**
  - **Landfill Cover Designs**



Landfill Screening Decision Tree

- Guides uses to pursue MNA, or
- Complete detailed remedial alternative assessment to mitigate CAH plume risks



Remedial Alternative Assessment Decision Tree

- Addresses necessity of Source Remediation
- Pursue bioreactor options
  - Anaerobic
  - Aerobic
- Pursue other, non-bioreactor remedial options

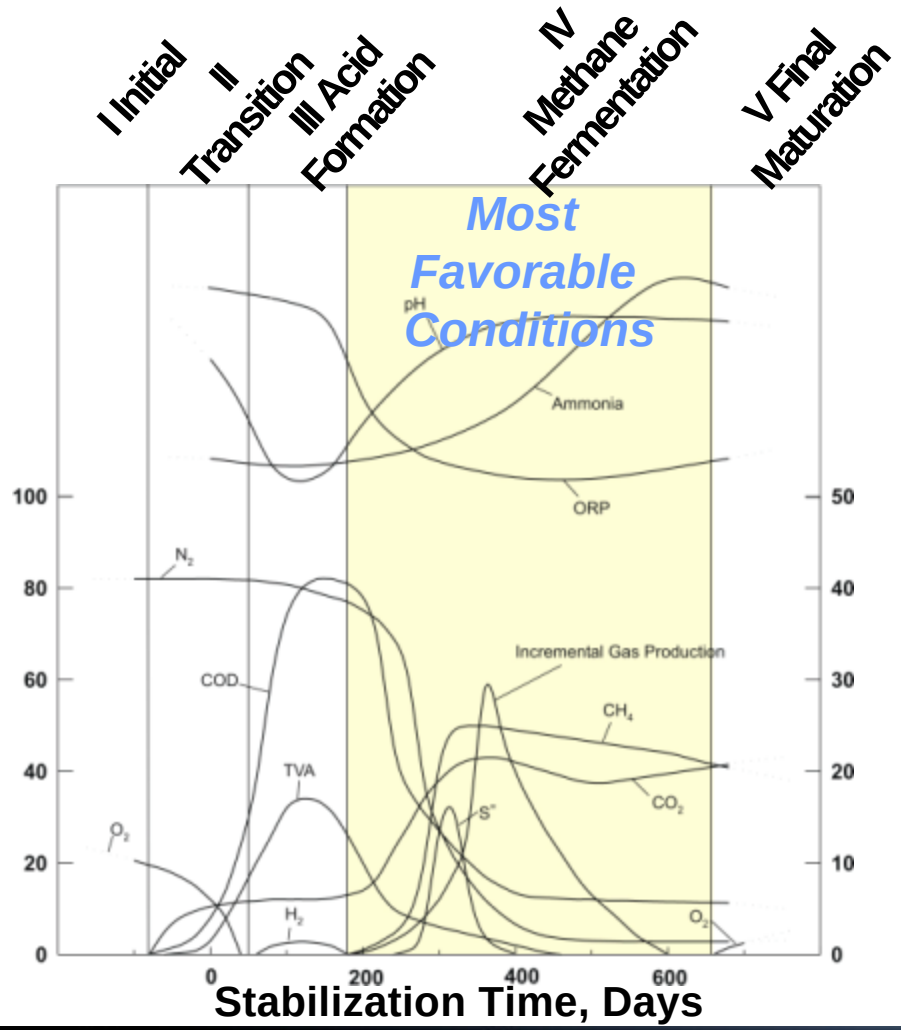
Elements of Successful Bioreactor Formation

- **Collecting and controlling leachate as it is generated**
- **Effectively redistributing leachate throughout the landfill**
- **Creating *in situ* treatment zones that promote robust microbial activity**
- **Managing landfill gases**

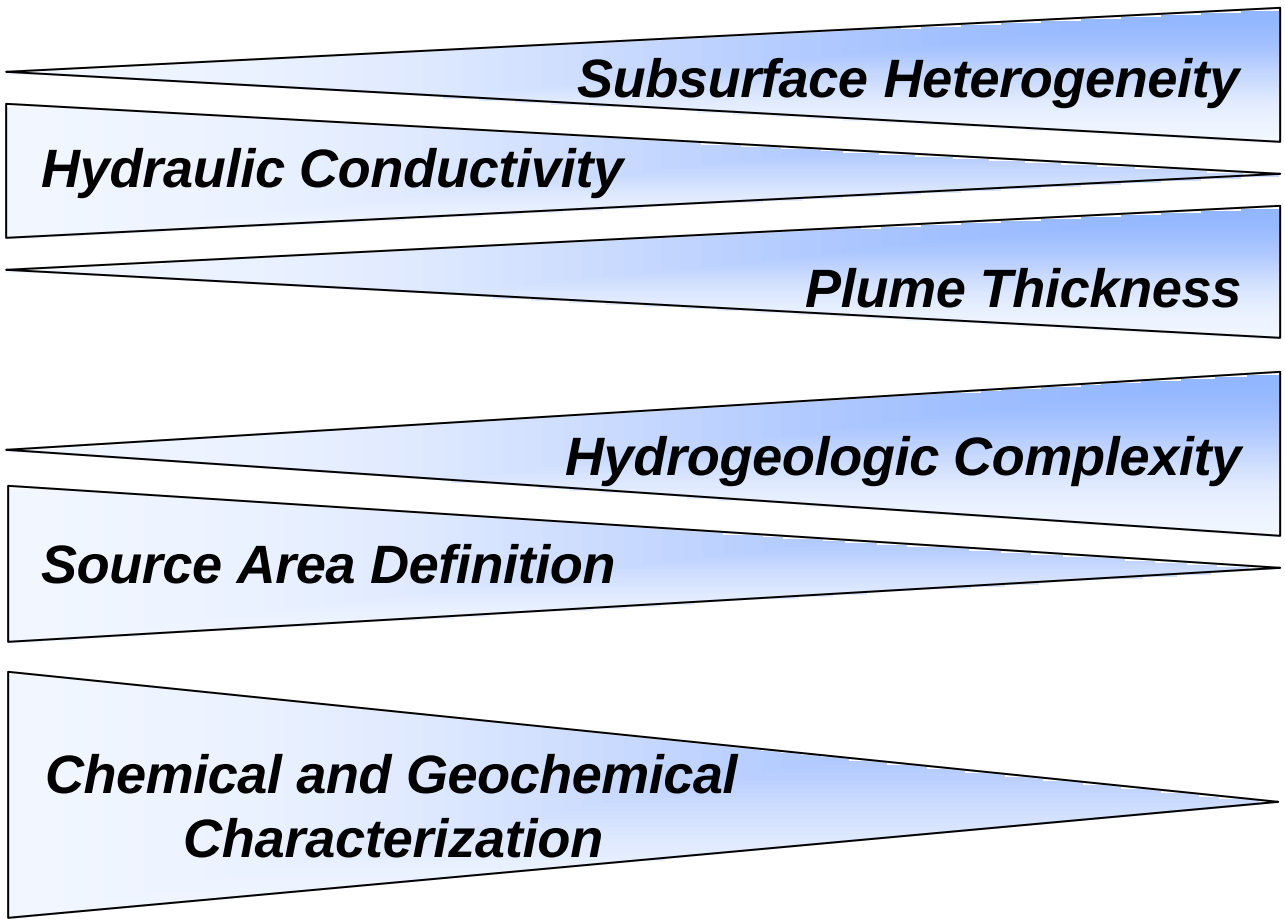
Favorable Conditions for Bioreactor

- Dissolved plume can be contained by extracting groundwater at a rate that can be reapplied within the landfill
  - Capacity of landfill to assimilate recirculated water not exceeded
  - Optimal moisture content required to operate an effective bioreactor not exceeded
  - No excessive leaching or leachate seeps
  - No undesirable alteration of hydraulic or geochemical conditions

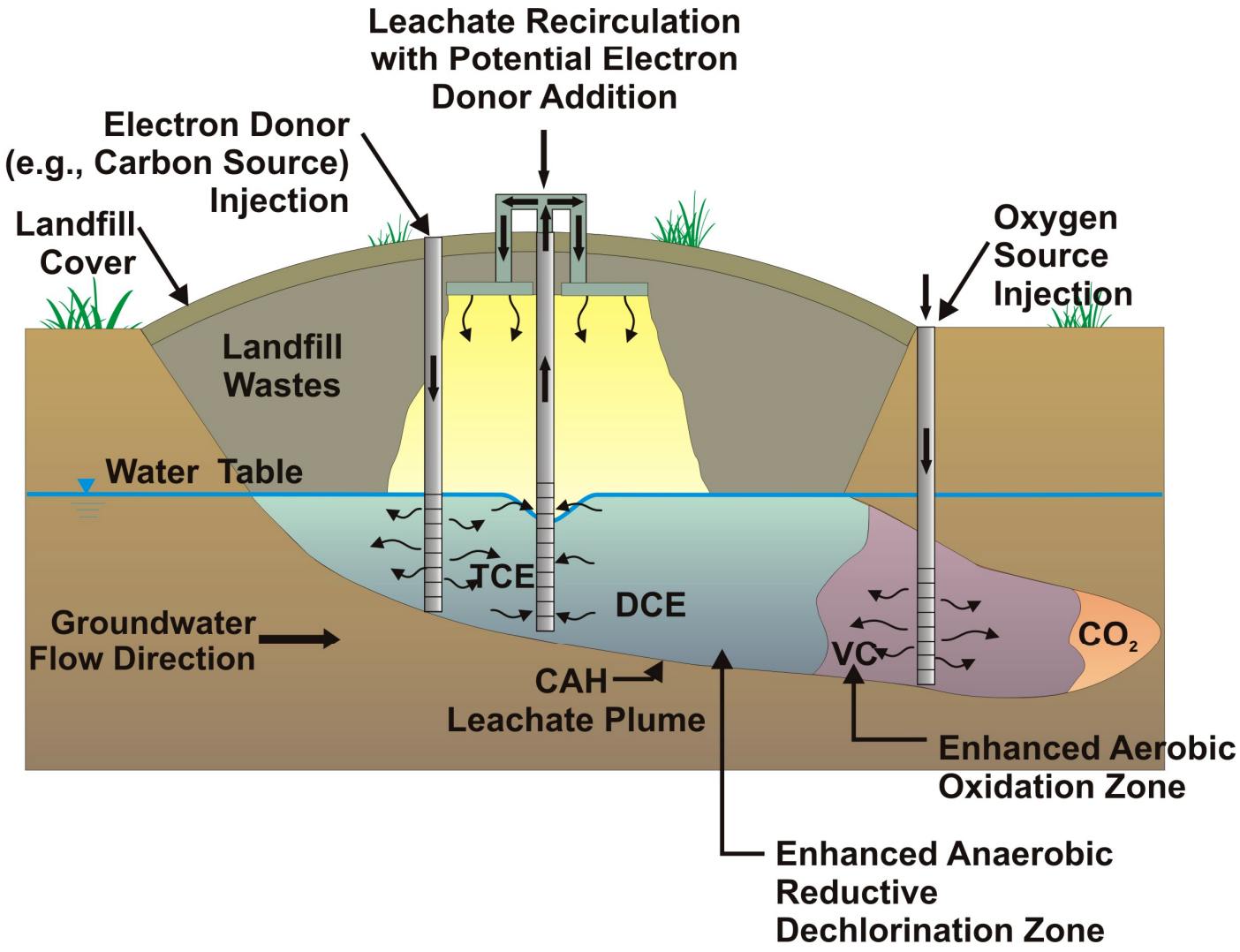
Phases of Landfill Waste Stabilization



Site Characteristics Influencing Bioreactor Operation and Effectiveness



One Scenario: Creation of Sequential Enhanced Anaerobic and Aerobic Zones Beneath a Landfill



Bioreactor Costs

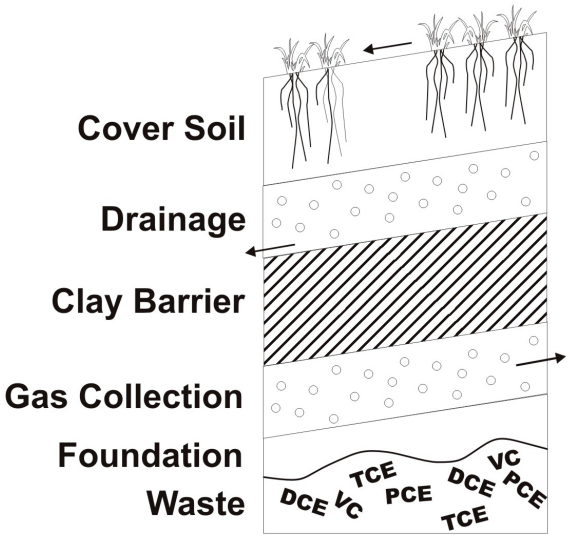
- **Estimated total system cost for unlined landfill**
  - **collection/recirculation of leachate-contaminated groundwater and bioreactor construction with mulch sublayer -- $100K to $140K per acre**
  - **O&M -- $60K to $80K per year**

Bioreactor Costs (cont.)

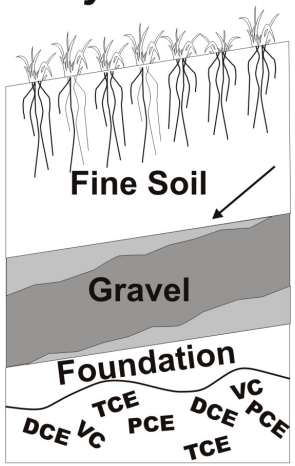
- **Actual Case Studies for Lined Landfills**
  - **Construction costs of $35K to $148K per acre (compared to ~$450K per acre for RCRA cover)**
  - **O&M costs of $64K to $300K per year**
  - **Annual cost savings for full-scale operating bioreactors of $75K to $500K compared to life-cycle cost increase of $1.40 - $2.15/ton in favor of dry landfills**

Selected Landfill Cover Types

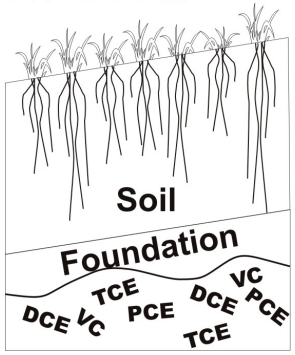
Conventional Cover



Capillary Barrier

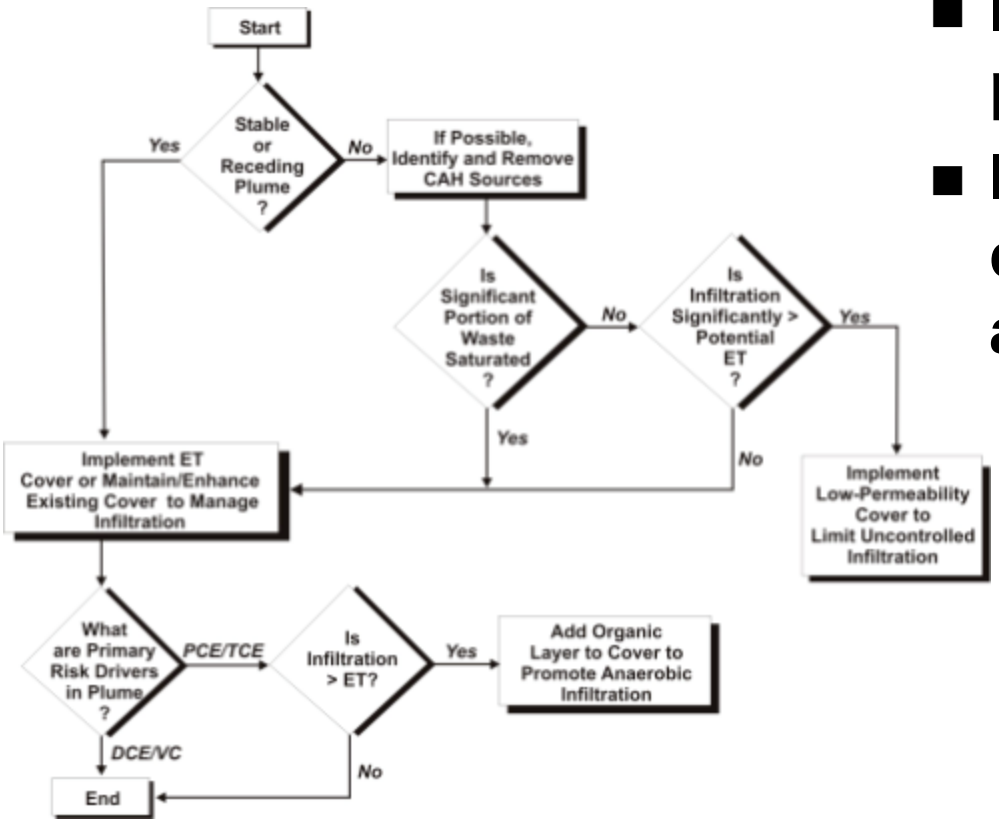


ET Cover



After Weand et al., 1999

Landfill Cover Designs Decision Tree

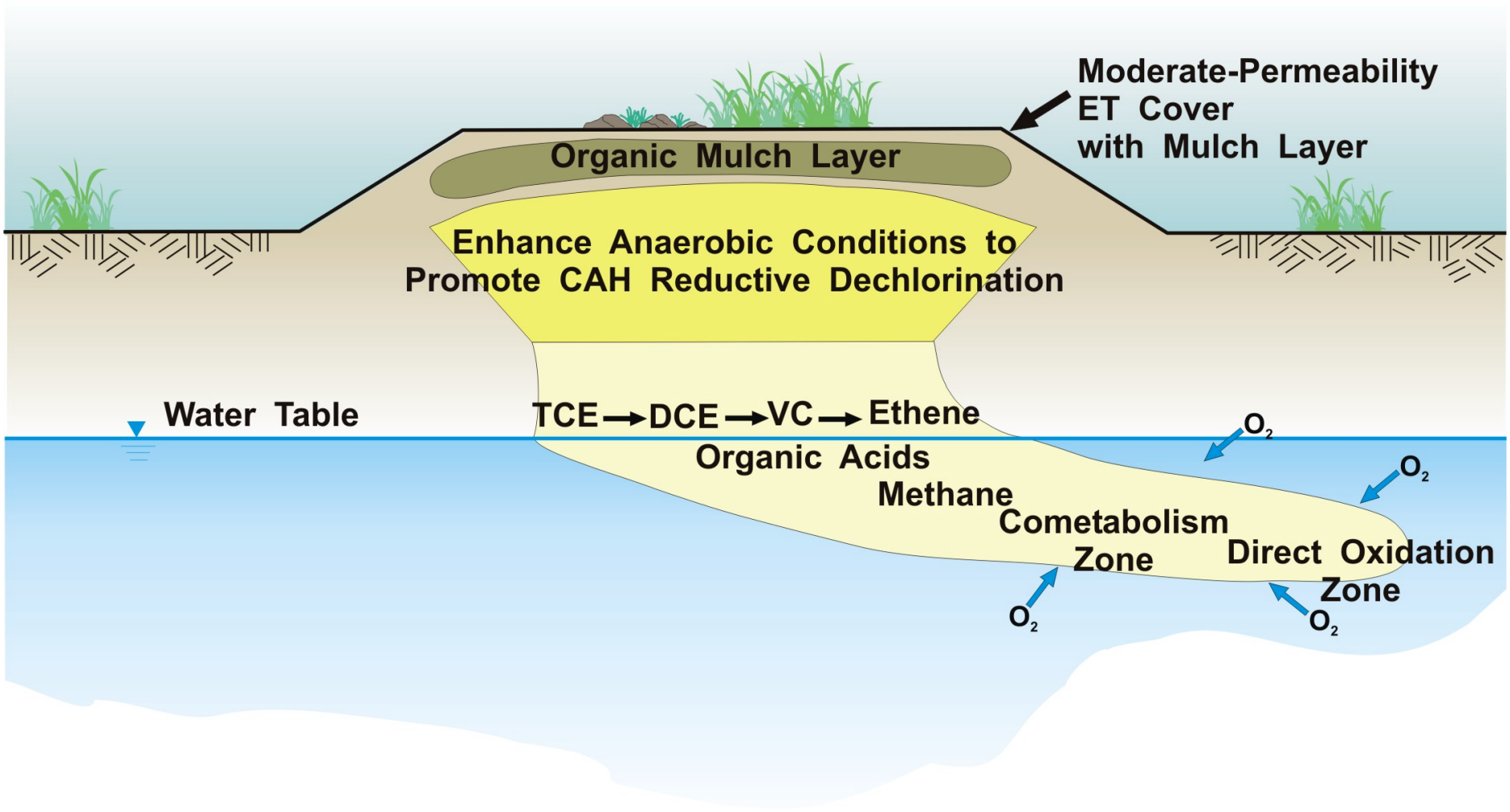


- **Implement low-permeability cover, or**
- **Implement vegetative cover, with or without an organic sublayer**

Conditions Conducive to ET Covers

- Significant portion of source at least seasonally saturated
- Precipitation rates and/or vadose zone permeability/thickness allow controlled infiltration

Use of Organic Layer to Enhance Reductive Dechlorination of CAHs



Phase II Field Test

- Funded by ESTCP
- Site Selection/Regulatory Approval currently underway
- Two 30’ x 30’ test plots
  - #1 – ET cover with mulch sublayer, no recirc.
  - #2 – Leachate recirculation through mulch sublayer
  - 1 year O&M